Exploring a Theoretical Framework and System Dynamics Model for Innovation and Sustainability within the Management of Projects Paradigm

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ABSTRACT

Anthropogenic climate change provides the context for the emergence of new challenges within the project management discipline. The scholarly research of Peter Morris can contribute to addressing these discipline challenges. This research builds upon the Management of Projects (MoP) paradigm and develops connections with systems understanding to support project practitioners in considering project sustainability decisions.

The Innovation, Sustainability and Management of Projects (ISMP) framework, introduced in this paper, incorporates an extension to the project life cycle model, introducing an 'ecosystems impact' phase, and it positions Innovation and Sustainability understanding into the MoP paradigm. MoP is associated with a holistic perspective which can be linked with the Systems Movement. An overview of some key ideas and theories connected with this Movement are provided, which supports the selection of System Dynamics technique for an approach to connect decisions and understanding within project management practice and across the project life cycle. A completed renewable energy project from Colombia is used as the case study for this exploratory research. A combination of the ISMP framework, project data, and stakeholder participation is used to inform the development of a System Dynamics model as a relevant approach to support strategic decision-making for the sustainability impact of proposed interventions.

The systems approach developed connects MoP, sustainability and innovation and has potential benefits for project practitioners navigating decisions for sustainability across the project life cycle.

Keywords

Engaged Scholarship, Innovation, Management of Projects, Sustainability, System Dynamics, Systems Movement.

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INTRODUCTION

Anthropogenic climate change (IPCC, 2022; 2021) is a serious global issue which impacts all societies. The emission of greenhouse gases (*e.g.* carbon dioxide) is a key driver of climate change which leads to flooding, drought, and wildfires (Morris, 2017). Concern to slowdown or reduce temperature rises has led to the UN climate change conferences (conference of the parties (COP)), and in 2015 a target limit of 2^0 C rise over pre-industrial global level by 2030 was agreed. The Association for Project Management (APM) acknowledges that "*the planet earth is in a perilous position with a range of fundamental threats*" (quoted in Silvius and Schipper, 2014, p.64). Critically, Morris (2017, p.2) considers *".... the potential impact of climate change and what project management as a discipline could, and should, be doing about it.*"

The project management discipline contributes to addressing contemporary societal problems and is emerging as an important practical profession. Morris (2017; 2013) argues that project management is a discipline concerned with definition as well as delivery, following projects throughout their life cycle. Furthermore, the APM, as advocates of project management, recommend the use of different tools and techniques, and applying practices, processes and procedures by professionals having specialist skills, which collectively form a body of knowledge (APM, 2019; PMBOK, 2017). However, Morris (2017) contends the discipline is too focused on these practices and tools rather than its impact and outcomes of real value. In response to Anthropogenic climate change, project professionals may need to extend their attention on the impacts of project decisions into the operational life of project outputs. This paper supports this proposition and presents a framework and tool to support project practitioners in pursuing such developments throughout the project life cycle. Pursuit of an extended agenda that embraces sustainability provides the context for further evolution of the discipline. It will need to adapt both theoretically and practically to these challenges.

Morris (2017) links both mitigation (*i.e.* reducing the incidence of climate change) and adaption (*i.e.* responding to its consequences) with project front-ending (*i.e.* scoping and definition). The capabilities over decision-making in the development of projects and in their delivery of innovations, affect the impacts that projects deliver and societies' abilities to transform to meet the challenges of climate change. Additionally, sustainability is becoming an important topic in project management (APM, 2019; Morris, 2017; Silvius et al., 2012), and Silvius and Schipper (2014) highlight some dimensions (*e.g.* recognition of project context, stakeholder identification, project success) that impact on the current practices of project management.

The work of Peter Morris assists with these challenges through connecting aspects of innovation and sustainability with the Management of Projects (MoP) paradigm (Morris, 2013; Morris, 1994; Morris and Geraldi, 2011; Morris and Hough, 1987). MoP broadens both theory and practice of the profession and encourages a holistic approach to achieving both short and long-term project success. This research builds upon the MoP paradigm and develops connections with systems understanding to support project practitioners in considering project sustainability decisions. The

Innovation, Sustainability and Management of Projects (ISMP) framework incorporates an extension to the project life cycle model, introducing an 'ecosystems impact' phase, and it positions innovation and sustainability understanding into the MoP paradigm (Calderon-Tellez et al., 2023). It highlights gaps in emerging expectations of project practice, connected to the strategic envelope and project front-end.

To further enhance the ISMP framework, System Dynamics (SD) technique (Forrester, 1961) is applied in developing an approach to connect decisions and understanding across the project life cycle. Working with a case study of a solar energy project, a SD model is developed as a strategic decision-support tool for assessing sustainability viability of proposed interventions of the project. An illustrative decision and modelling scenario for the project is developed and discussed.

The study develops and demonstrates a systems approach to support project practitioners in decisions over sustainability viability of project interventions. In this approach SD technique is used to connect MoP, innovation and sustainability perspectives into projects in practice.

In introducing the foundations of this work, the next section discusses three areas of literature: MoP, Systems approaches, and project management connections to innovation and sustainability. Section 3 describes the ISMP framework and the SD approach developed. Section 4 introduces the case study project, applies the approach and demonstrates modelling for an illustrative scenario. Section 5 is a discussion section and Section 6 concludes.

LITERATURE

This section introduces three strands of literature. Firstly, the Management of Projects paradigm and its differentiation from previous treatment of the project management discipline is introduced. Systems approaches are then outlined and their fit within the project management field discussed. Finally, research considering innovation and sustainability within project management practice is discussed. These three areas underpin the development of the ISMP framework and of a system dynamics approach for applying the framework described in section 3.

Peter Morris's Work and Management of Projects

Winter et al. (2006) identify three distinctive theoretical strands within the project management discipline. The first strand is the most dominant, it is characterised as traditional project management and it emphasises planning and controlling with respect to the delivery phase of the project life cycle. The second strand focuses on organisational structure as a way of achieving integration and task completion. The third strand emphasises a broader project management perspective and the work initiated by Peter Morris on the Management of Projects (MoP) paradigm is a key focus. The first (traditional) and third (alternative) of Winter et al.'s (2006) theoretical strands are of relevant interest and guide this section of the literature review.

Traditional Project Management

The first theoretical strand (Winter et al., 2006) emerged in the 1950s and 1960s and had an engineering management nature (Morris and Geraldi, 2011). Importantly, innovation has an early connection with project management during this period (Davies, 2017). The US Department of Defense stressed the use of tools and techniques (*e.g.,* Program Evaluation and Review Technique (PERT)) which are central to traditional project management and the delivery phase of the life cycle model (Morris, 2013).

The project management profession emerged through the development of procedures, tools and methods that were connected with aerospace and defence industries within the context of the cold war era and Soviet threat (Morris 2011)**.** This eventually led to the manifestation of the Project Management (PM) Institute and respective body of knowledge (BOK) standards. Interestingly, PMBOK (2017, p10) defines project management as "*the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements"*, and projects as "*a key way to create value and benefits in organisations. In today's businesses environment, organisational leaders need to be able to manage with tighter budgets, shorter timelines, scarcity of resources, and rapidly changing technology…*".

This theoretical strand established the boundary of traditional practice of the profession, which places an emphasis on planning, monitoring and controlling of project delivery (Morris and Geraldi, 2011). It is also concerned with efficiency, addressing '*the how*' question, '*doing the project right*' that delivers the project on time, in budget and to quality, and is connected with project management success (Atkinson, 1999; Cooke-Davies, 2007). This project management focus, in terms of cost, time and quality, can be connected with short-term management decision objectives.

Alternative Project Management

The alternative (third) theoretical (Winter et al., 2006) strand emphasises a broader view of project management which acknowledges the importance of project front-ending, managing exogenous factors as well as the traditional delivery endogenous ones. The numerous studies of causes of failures such as client driven changed specification and poor design management (Edkins et al., 2013; Morris, 2013; 2002; 1994; Morris and Hough, 1987) reinforces this strand. Morris (2002) argues that focusing on delivery alone without consideration of context and strategy usually leads to unsuitable objectives and therefore project failure. These important findings led to the development of the MoP paradigm which is described by Morris (1994, preface) as "*the management of the process of establishing the project's objectives and its definition; of assessing it so that is set up with the maximum chance of being successful technically, commercially, socially, etc. for all the parties ('stakeholders') it affects; and of accomplishing it efficiently and effectively"*.

MoP (Morris, 2013; Morris and Geraldi, 2011) has three distinctive levels, namely, technical core, strategic envelope and institutional context. The first level, the technical core is associated with traditional project management. The second level, strategic envelope, includes project front-ending and shields the technical core from environmental turbulence. Moreover, it has a connection with effectiveness, addressing '*the why*' question, '*choosing the right project'*. The work of Miller and Lessard (2000) with respect to *benefits* and *value* also informs project success (Cooke-Davies, 2007) and is associated with the strategic level. Project success can be viewed as long-term management decision objectives. This level also has a relationship with exploratory and innovative projects (Lenfle, 2016). The third level, the institutional context endeavours to facilitate an environment (*i.e.* '*outside and around the project*') (Morris and Geraldi, 2011, p.22). Developments in Section 3 of this paper will focus on the connectivity of strategic envelope and technical core. Morris and Geraldi (2011) assert that the strategic envelope and technical core are linked within the project and position the institutional context outside the project.

Winter et al. (2006) propose new directions in project complexity, social process, value creation, project conceptualisation and practitioner development which can be integrated into MoP. These offered new directions broaden both theory and practice with respect to complexity, and support MoP endeavours to be an '*open system*' that adapts to environmental changes.

Additionally, Project front-ending (Morris, 2011) emerged as an important development, within the alternative strand, and can be considered to be a meta-phase of the project life cycle. It should establish the desirability, feasibility and viability (Brown, 2019) of a possible innovative project. Project front-ending has been shaped through the work of Edkins et al. (2013), Fuentes, et al. (2019), Morris (2011; 2002), and Williams et al. (2019, 2009). Additionally, project back-ending has been established by the work of Artto et al.(2016) and Morris (2013). Moreover, projects are seemingly shifting towards strategy (Cooke-Davies et al., 2009) and creating value (Green and Sergeeva, 2019; Winter et al., 2006; Winter and Szczepanek, 2008). Project front-ending, project delivery and project back-ending are important meta-phases of the project life cycle and key elements of the MoP paradigm.

Role of Systems Approaches

Many of the traditional project management tools and methods, used for *tactical* and *operational* project delivery decisions, can be considered as systematic approaches (Pinto, 2013; Meredith and Mantel, 2012). Morris and Geraldi (2011) suggest traditional systematic approaches may not be adequate for the issues and complexities associated with broader project management consideration (*i.e.* outside the delivery phase). Morris (2002) suggests that systems thinking could offer scientific rigour and knowledge to management in dealing with greater levels of complexity in the MoP paradigm.

The Systems Movement

This section highlights aspects of the Systems Movement that underwrite the connectivity with project management. Many management academics have explored different aspects of complexity (Baccarini, 1996; Williams, 2002, 1999). Systems Thinking attempts to tackle issues of irreducible complexity through a form of thinking based upon wholes and their emergent properties (Jackson, 2019). Checkland (2012) asserts that a system can be viewed as an adaptive whole, which can evolve as its environment changes (*e.g.* climate change) or delivers unforeseen shocks (*e.g.* COVID-19) to it. The identified system may contain functional subsystems, and perhaps, as a whole, be a functional part of a wider system (Checkland, 2012).

In exploring living organisms, as an open system (or whole) rather than a set of components and their relationships between them, Von Bertalanffy (1950) highlighted the difference between systems that are open to their environment and those that are closed.

Open Systems can exchange materials, energy, and information with its environment. Closed systems do not exchange materials and can be isolated from the wider system. Importantly, to maintain any hierarchy of open systems requires a set of processes in which there is communication of information for the purpose of control (or regulation) (Checkland, 1987, 1981).

Systems Thinking is an epistemology underpinned by two pairs of ideas, namely: emergence and hierarchy, and communication and control (Checkland, 2012, 1987, 1981). These pairs of ideas are derived from two different theoretical strands of thought. The first theoretical strand of systems thinking is connected with biology which examined plants and living tissue. The notion of organised complexity is the focus of thinking in systems. Moreover, the general model of organised complexity is that there are hierarchical levels of organisation which are more complex than the one below. Checkland asserts each level is characterised by emergent properties which do not exist at the lower level.

The second theoretical strand of systems thinking is derived from control theory, and from information and communication engineering (Checkland, 1987, 1981). A link between control mechanisms studied in the natural systems and those engineered man-made systems was through cybernetics. Wiener's (1948) cybernetics work contributes to communication and control and Wiener and Biglow recognised the importance of the process of feedback loops (*i.e.* positive and negative) (Checkland, 1981). Furthermore, all control processes depend upon communication and flow of information in order to maintain a '*steady state*' of the hierarchical open systems. This engenders thinking systemically within the identified open system (or whole).

Hard and Soft Systems Approaches

Checkland (1981) discusses problem-solving applications of systems approaches to real-world problems being divided into three areas: hard systems thinking and methodologies (*e.g.* Systems Engineering), aid to decision-making (*e.g.* RAND Systems Analysis), and Soft Systems thinking and methodologies (e.g. Soft Systems Methodology (SSM). However, responding to Morris's (2012) critique of the degree to which key systems ideas are represented within Systems Analysis, the two systems-thinking approaches (hard and soft) are considered here.

Hard systems thinking and associated approaches, such as cybernetics, assume systems are pre-existing in the real-world. The systems' objectives are defined and are not problematic, and alternative ways of achieving them can be modelled and compared through identified criteria (Checkland 2000; 1981).

Soft Systems Thinking attempts to tackle ill-structured problems which are a feature of social situations (Checkland, 2012; 1987). It is assumed that the social world is being constructed and reconstructed through conversations amongst different stakeholders. Soft systems approaches can be considered a process of inquiry and learning, and systems are used to organise complexity for conversations.

Although hard systems approaches have been applied in the systematic tools and methods in traditional project management (focused on the project delivery phase), soft systems approaches come to the fore in the development of the MoP paradigm and the consideration of projects more as open, rather than closed, systems (Morris, 2002).

MoP and Soft Systems

The development of MoP (Morris, 2013, 1994) has broadened both theory and practice of project management. Furthermore, it extends the life cycle model to encompass both project front-ending and back-ending. Morris (2002) advocates the connectivity of soft systems thinking and soft approaches (*e.g.* SSM (Checkland, 2000, 1981) and Causal Loop Diagrams (Qualitative SD) (Senge, 2006; Sterman, 2000)) with project front-end practice.

MoP takes "*a more holistic perspective and is theoretically catholic"* (Winter et al., 2006, p.640). Kapsali (2013) argues that holism is strongly related to boundary management and developing flexibility in evolving project processes. Fundamentally, holism, interconnectivity, integration and open systems theory underwrite this alternative theoretical strand and the MoP paradigm. Soft approaches are more suitable for addressing problematic situations (Checkland, 1981) associated with project front-ending. Winter (2006) has applied SSM (Checkland, 1981) to broaden the practice and further substantiate the identified research directions (Winter et al., 2006) within the MoP paradigm.

System Dynamics

Although System Dynamics (SD) was initially developed and applied separately from Systems Thinking, connectivity between the approaches was established later (Richardson et al., 1994). Lane and Jackson (1995) and Schwaninger (2006) are among those who have connected system dynamics with the Systems Movement. The SD technique was developed by Jay Forrester in the 1950s to simulate system behaviour over time that includes nonlinear dynamics, complex systems, feedback loops, and delays (Forrester, 1961; Sterman, 2000). A fundamental strength of SD is that it can explore '*new states*' of an identified open system. Connected to systems thinking, SD models can represent an open and/or closed system (Coyle, 1996).

In a review of the application of SD within the delivery phase of the project life cycle, Calderon-Tellez (2022) considers these models as systemic explanations of the project life cycle model and highlights a shift in interest from systematic to systemic decision support modelling for project management. However, in application to the delivery phase of projects, SD tends to have been applied in a *hard systems mode*. For example, Abdel-Hamid and Madnick (1991) developed an SD (or systemic) model to illuminate the structural complexity (Jackson, 2019; Williams, 2002) of the delivery life cycle process within software projects. This SD model is considered to be a closed system as it is isolated from the environment (*i.e.* the project is a given) and fundamentally uses endogenous variables. Abdel-Hamid and Madnick's (1991) focus on developing an *objective model* and the research design requires various software professionals to confirm different aspects the model. In this approach key stakeholders of that relevant complex situation need to confirm all (or the whole) aspects of the subjective systemic model in order to have structural explanatory understanding and therefore confidence in the predictions.

In developing SD to apply beyond the delivery phase into the wider MoP paradigm, there is an opportunity to develop SD models with a softer systems approach. This can move to building SD models using a more subjective, participative and relevant approach that links with the broad SD practice and integrative social theory (Bell et al., 1999; Burrell and Morgan, 1979; Lane, 1999).

Sustainability & Innovation in Project Studies

Anthropogenic climate change (IPCC, 2022; 2021) is the most pressing challenge that impacts the environment, economies and societies. Within the many responses to this, there have been significant academic conversations about climate change, sustainability and sustainability development within the project management profession (APM, 2019; Huemann and Silvius, 2017; Morris, 2017; Calderon-Tellez et al., 2023). This provides the context for a further evolution of the MoP paradigm and the discipline. And implies that sustainability should be integrated with the MoP paradigm addressing both theoretical and practical knowledge gaps.

Morris (2017, p. 4), defines sustainability as "*the capacity to endure: we are talking of the endurance of systems and processes*" and Brundtland (1987, p.41) describes sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". Assessing sustainability and sustainable development can combine social, economic, and environmental factors, known as the triple bottom line (TBL) (Elkington, 1999). In projects this assessment can be linked to measures of project outcomes (Gimenez et al., 2012; Martens and Carvalho, 2017; Silvius, 2017; Silvius and Schipper, 2014; Calderon-Tellez and Herrera, 2023).

Silvius and Schipper (2014) offer a definition for sustainable project management (SPM) "*Sustainable project management is the planning, monitoring and controlling of project delivery and support processes, with consideration of the environment, economical and social aspects of the life-cycle of the project's resources, processes, deliverables and effects, aimed at realising benefits for stakeholders, and performed in a transparent and ethical way that includes proactive stakeholder participation*" (2014, p. 79). Critically, Silvius and Schipper suggest sustainability could impact project management at different levels, namely, shift in scope, shift in project management paradigm, shift in mind set of the profession.

Sustainability is not only about being '*green*' through the prudent use of all resources and reducing waste (Gladwin et al., 1995; Lindsey, 2011). It is an opportunity for SPM enhancement throughout the integrated project life cycle identifying indicators (Fernández-Sánchez and Rodríguez-López, 2010; Stanitsas et al., 2021) or critical success factors (Kiani Mavi and Standing, 2018) that allow an interconnected balance between different TBL aspects.

A shifting focus towards sustainability within project development, delivery and success also provides the context for greater intensity of innovation within projects and project management. It increases the need for understanding of innovation and dealing with complexity within project management practice.

Innovation and project management have had connectivity since the Second World War (Davies, 2017; Lenfle and Loch, 2011). Calderon-Tellez (2022) identifies several innovation and project management frameworks (*e.g.* the diamond approach framework (Shenhar and Dvir, 2007); the Strategic Project Management (SPM) framework (Andersson and Chapman, 2017). Moreover, Davies et al. (2018) suggests there is a necessity to theoretically cross-fertilise innovation with project management. It is argued that aspects of innovation and MoP need to connect (see Figure 1, below), and there is interest in *process* and *product* innovation (see Figure 1 and Figure 4) (Davies and Hobday, 2005; Tidd and Bessant, 2018), *managing* innovation (Tidd and Bessant, 2018) and *open* innovation (Chesbrough, 2003). Furthermore, the innovation challenge can be about developing something that may never have been done before (Tidd and Bessant, 2018, p. 19).

Responding to these additional demands and complexity faced by project practitioners, a framework has been developed extending MoP to incorporate consideration of sustainable viability of innovative projects. This is presented in the following section.

DEVELOPMENTS FOR THEORY AND PRACTICE

The ISMP framework that is introduced in section 3.1 connects understanding of MoP, innovation and sustainability to aid project practitioners in considering project sustainability decisions. Section 3.2 introduces a SD tool that has been developed to aid the implementation of these ideas and as a way to tackle increasing levels of complexity in these contexts.

Innovation, Sustainability and Management of Project (ISMP) Framework

The ISMP theoretical framework (see Figure 1) has been developed through engaging with relevant literature to respond to the problem of developing appropriate and successful projects in the context of climate change. This framework builds on the MoP paradigm. It extends the project life cycle model and positions Innovation and Sustainability understanding into the MoP paradigm. The ISMP framework can be viewed as an adaptive system.

Building on MoP

Connecting with systems approaches (see section 2.2), the MoP paradigm takes a holistic perspective to achieving both project management success and project success. The technical core, linked with traditional project management and the delivery phase, can be viewed as a closed system where the project and its objectives are pre-defined, and the "*activities are endogenous*" (Pich et al., 2002, p.1012). The MoP paradigm shifts project management from a closed system to an open system perspective with the introduction of the strategic envelope (see Figure 1). The strategic envelope hierarchical level incorporates considerations of strategy and value creation (Morris, 2013). The MoP paradigm also integrates the meta-phases project front-ending and back-ending into the project life cycle model.

Building on this understanding of the MoP paradigm and examining the needs of project practitioners developing and delivering projects responding to the threats posed by climate change, the ISMP framework (see Figure 1) is proposed as a way of structuring strategic decision-making for projects for sustainability.

Connecting Elements for Practice

The anthropogenic climate change context creates the need to consider environmental, sustainability and sustainability development issues of proposed innovative projects. There is a requirement for a broader concept which can incorporate relevant multi-dimensions (or attributes) and explore their individual and interconnected dynamic impact over time.

Viability (Brown, 2019) is associated with cost, benefits, profit, and relevant stakeholder values. It can be connected with short-term (*i.e.* project management success (Cooke-Davies, 2007)) and long-term (*i.e.* project success (Cooke-Davies, 2007)) management decisions that are respectively linked with delivery phase and back-ending (or operations) phase of the project life cycle. Considering long-term impacts of project decisions would benefit from an approach to sustainable viability evaluation of possible innovative projects. However, this reaches far into the project back-end phase. In response, an ‘ecosystems impact’ phase (incorporating termination) is added to the project life cycle (see Figure 1). The ecosystems impact idea is intended to cover a broad range of impacts, including sustainability. It encourages all project management professionals to consider long-term dynamic impacts of their innovative solutions upon relevant ecosystems. This additional life cycle phase reflects the evolving values of society over climate change concerns, which are also reflected in the evolving approaches of the project practitioner organisations (e.g. APM, 2019).

Considering sustainability across the project life cycle, and into the ecosystems impact phase, further requires attention to understanding of both innovation and sustainability for project practitioners. Identified relevant innovation and sustainability theories provide further content for MoP and have been incorporated into the development of the interdisciplinary ISMP framework (see Figure 1). Innovation is an intellectually rich discipline, and it can be connected with exploration and/or exploitation activities which can be associated with front-ending and delivery phases of the life cycle model (see Figure 1). Features of innovation are conceptualised as a sub-system within the MoP strategic envelope concept and Figure 1 also shows a selection of relevant innovation theories within that sub-system. Sustainability also is conceptualised as a sub-system within MoP’s strategic envelope. A selection of relevant sustainability theories, with respect to innovation responding to real-world problems, are identified and shown in the sub-system (see Figure 1).

The ISMP framework as presented in Figure 1, aims to address the emerging theoretical gaps facilitated by anthropogenic climate change. The framework is also considered an open system and utilises systems thinking ideas. The systems thinking pair of ideas (*i.e.* emergence and hierarchy) encompasses all the metaphases of the extended life cycle (*i.e.* front-ending, delivery, back-ending and ecosystems impact). Moreover, this broadens the theoretical framework for exploring the integrated processes of this complex life cycle phenomenon.

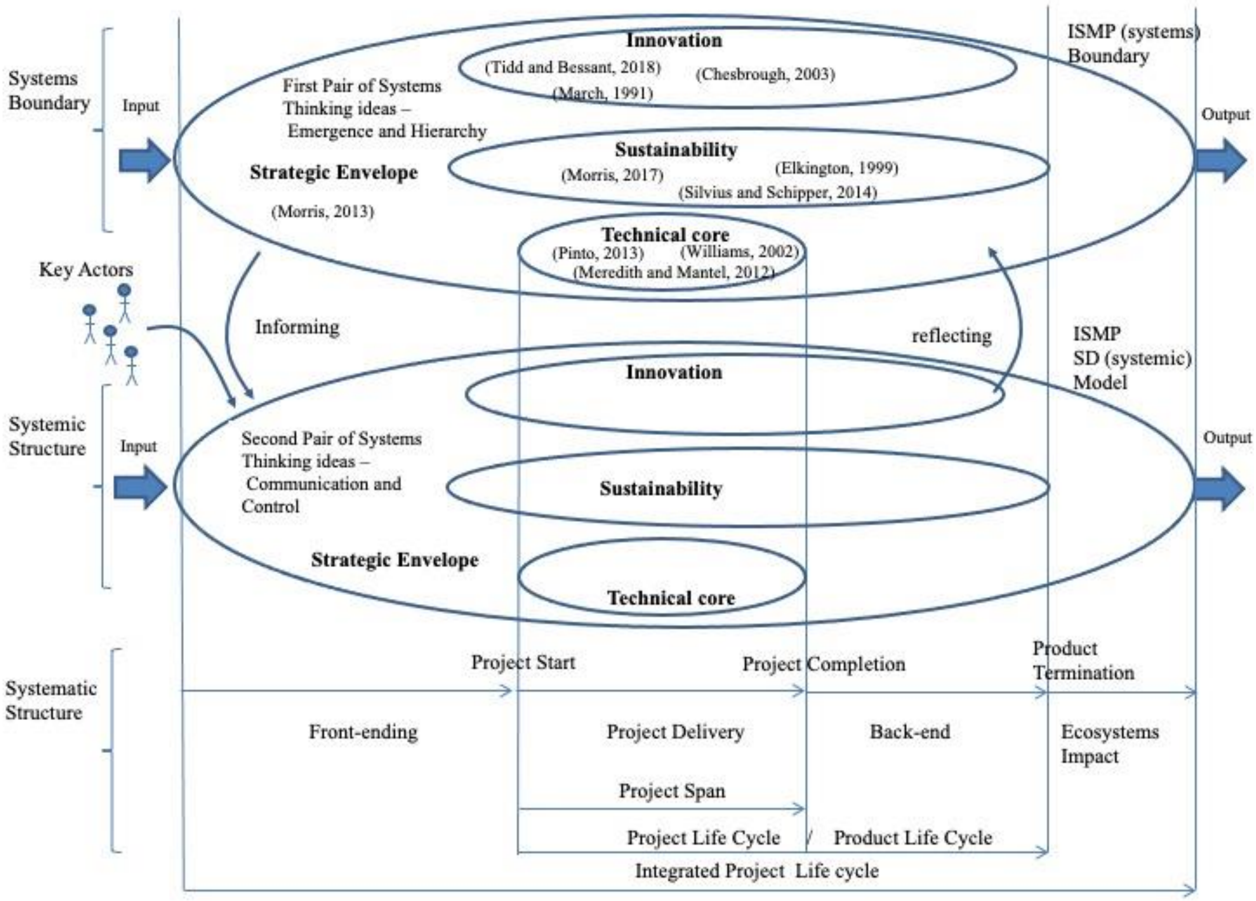

Figure 1: ISMP Extended Life cycle Model (building on Calderon-Tellez, 2022)

System Dynamics Implementation Tool

The ISMP theoretical framework highlights gaps in project management practice. These gaps include strategic decision-making, long range planning and scenarios planning. These practice gaps are connected with the strategic envelope and project front-ending. To support the application and use of the ISMP framework, an approach is needed to connect decisions and understanding across the project life cycle. SD technique underpins the approach that is developed and applied here. The SD approach developed, and the associated case-specific strategy, apply across the strategic envelop represented in the ISMP framework (Figure 1). Working with a case study of a solar energy project, a system dynamics model is developed based on the ISMP framework and representing its interactions with a particular project.

The systems thinking pair of ideas – communication and control (Checkland, 1981) informs the selection of the SD technique in the development of a relevant systemic model. The aim is to illuminate the structural complexity (or 'systemicness') within the boundaries of the ISMP framework. SD is proposed as the appropriate technique to illuminate the interconnectivity of relevant processes (*i.e.* 'the content' and 'the means') and to explore sustainable predictive impacts. In the application of the approach developed in the solar energy project case study, the measures for sustainability are associated with the triple bottom line (TBL) of sustainability. Sustainability is considered in three domains: environmental, social, and economic. The assessment of a proposed project or approach in these terms evaluates its sustainability viability.

In the next section these theoretically informed ideas are applied in a real case study of a solar energy project. Viewed as an open system, a SD model has been developed, based on the ISMP framework, that incorporates both exogenous and endogenous variables. This case study illustrates the application of the ISMP framework (see Figure 1) in the construction of a SD model that can then be applied, through the use of different scenarios, to support decision-making of project practitioners. Benefit is provided by demonstrating the information connections and outcomes around sustainability and innovation for such a developing project.

APPLYING THE ISMP FRAMEWORK IN A CASE STUDY OF A SOLAR ENERGY PROJECT

Working with a solar energy project in Colombia, this research investigates the relationships between decisions developing through the project life cycle and the ecosystem impact phase added in the ISMP framework. A process applying System Dynamics (SD) technique to operationalise & communicate these connections into project practice and decision-making is developed. A SD model is constructed and evaluated and applied in an evaluation scenario.

Research Approach and Method

The engaged scholarship diamond model (Van de Ven, 2007) guides this exploratory research. Engaged scholarship aims to advance scientific and practical knowledge to complex problems within the professional domain. The application of this approach aligns with open systems theory and systems thinking (discussed in section 2.2) and connects stakeholder participation. The engaged scholarship diamond model (Van de Ven, 2007) has four activities, namely, problem formulation, theory building, research design, and problem solving. It emphasises the importance of iteration between these four activities to build understanding in context.

The ISMP framework has been developed to respond to the research problem: how to develop appropriate and successful projects in the context of climate change? The MoP paradigm is viewed as an open system that is extended in the interdisciplinary ISMP framework which adds the ecosystems impact phase to the project life cycle. Using this systems' understanding to consider the implications of this framework for project practice, this study selects the SD technique to reveal and communicate the structural complexity (Jackson, 2019; Williams, 2002) across this extended project life cycle.

Building on existing examples of SD research practice (e.g. Seki et al., 2020; Cosenz, 2017), the research design adopted develops a single case study of a sustainable energy project that is part of an electrical energy programme in Colombia. Cosenz (2017, p. 57) argues for a single case study approach as it "*illustrates and discusses an approach that combines such a framework with SD modelling*".

As projects responding to climate change whilst providing access to energy, the development of an energy programme, such as the Colombian programme considered here, needs to evaluate long and short-term sustainability considerations (linked with viability) of innovative approaches. This study is developed using an adaptive approach (Morris, 2017) and applies SD technique as a practical way to incorporate the eco-systems impact phase into project decision-making. The engaged process of developing the SD model bridges additional demands on the project management discipline (i.e. accommodating process complexity, strategy, long range planning, scenarios, short and long-term project objectives).

The combination of the ISMP theoretical framework, project data, and stakeholder participation (*i.e.* using their experiential knowledge) contributes to the process of developing a relevant and explanatory SD model. This can be viewed as an offered systemic dynamic hypothesis (developing Sterman's (2000) idea of a 'dynamic hypothesis') – making knowledge explicit. The systemic dynamic hypothesis reveals the relevant structural complexity of the life cycle process.

The SD model, as developed, is applied into problem solving mode for the project by developing and modelling an illustrative scenario (see section below). The development of the SD model, discussed in more detail in section 4.2.1., was conducted using VenSim software (version 8.2.0) and followed Sterman's (2000) SD modelling approach using project data and stakeholder interviews. The comparative predictive insights produced from the developed SD model with respect to the sustainable viability of two innovative technologies, are then outlined.

Renewable Energy Case Study (Case Study & Data)

The Ministry of Mining and Energy in Colombia is involved in an electrical energy programme to improve the quality of life of their citizens in various regions of the country. The ministry explores a range of energy generation approaches (*e.g.* from fossil fuel to renewable energy). Ministry civil servants and the Colombian military are key actors in the development and delivery of the programme. From within this programme a specific solar photo voltaic (PV) energy project has been selected for this research. Running from November 2017 to April 2019, the project aimed to provide energy access for 82 families located in the Orinoquia region, in the north-east of Colombia. Table 1 shows principal aspects of the solar energy case study.

In considering the implementation of Solar PV, the programme represents an important set of projects for Colombia. Colombia plans to implement 409 PV projects to generate 25,385 MW (Megawatts) from 2021 to 2026, which represents 48.63% of total energy projected in the target region (UPME, 2021). It is intended that Solar systems "*will contribute to rapid technology diffusion in the Colombian residential sector*" (Jimenez et al., 2016, p. 827) and the geography of the country lends itself to solar energy projects (López et al., 2020).

This research considers the Colombian case study suitable, as it allows the understanding of managing a highly complex energy project considering innovative approaches for sustainability. It is also worth highlighting that this case study is important for related developments in other countries, as it can offer new information in terms of the challenges and opportunities for the diffusion and expansion of solar energy projects.

The SD model for the project is developed using data provided by the Colombian Ministry of Mines and Energy: a data report from the solar PV energy project FAZNI-GGC-521-IPSE-074–2017 of the Colombian Ministry of Mines and Energy under Rad. 2019084512, and interviews with key actors that developed the project. Additionally, key internal reports were provided and access to other key stakeholders was facilitated by the ministry.

Table 1: Project information

Project	**FAZNI GGC 521 IPSE 074 – 2017**	
Objective:	Provide energy for 82 families	
Timescale:	Form 10 November 2017 to 30 April 2019	
Cost:	USD 540,839	
Types of Solutions:	Type 1: 60 solutions	Type 2: 22 solutions
Energy:	Type 1: 650-680 wp	Type 2: 975-1020 wp

Developing the SD model

The development of the SD model is guided by broad SD practice (Lane, 1999) and is connected with integrative social theory. Moreover, it is informed by the ISMP framework and through working with key stakeholders to illuminate the complexity of the life cycle processes. This approach leads to the offered systemic dynamic hypothesis within the extended theoretical boundary. Sterman’s (2000) SD modelling approach, followed here, has five main steps: 1) problem articulation, 2) formulation of a systemic dynamic hypothesis (represented in the Causal Loop diagram (Figure 3)), 3) formulation of a simulation model (represented in the Stock and Flow Diagram (Figure 4)), 4) testing, and 5) policy design and evaluation. Figure 2 shows the interaction of the steps with the real world, such as decision, strategy, and structure.

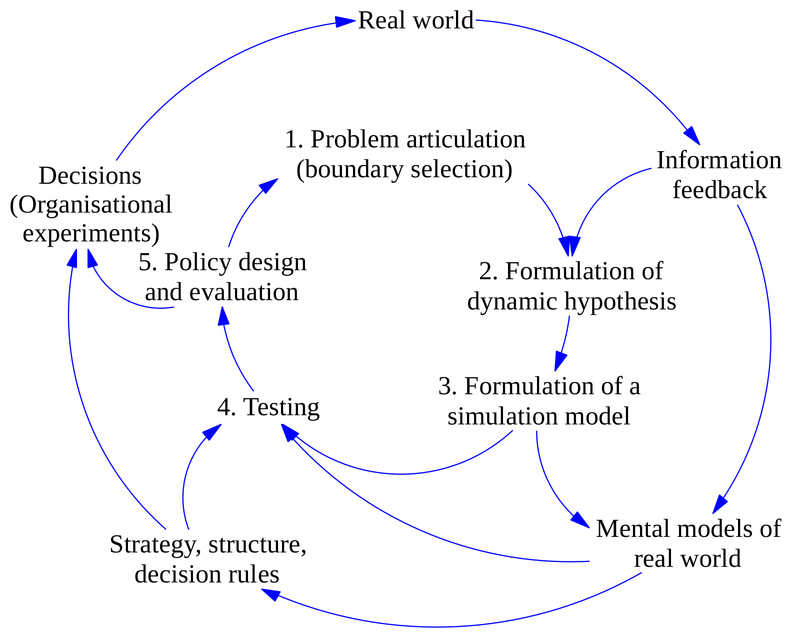

Figure 2: The iterative system dynamics modelling (Sterman, 2000, p. 88).

The combination of interviews with actors involved in the development of the project (2 interviews, each approximately 90 minutes) and Orinoquia residents (9 interviews, each of 30-60 minutes) identified relevant problems, and the ISMP theoretical framework contributed to the SD development process. Interviews with families involved in the project highlighted problems (*e.g.*, road accessibility) and needs (*e.g.*, a refrigerator at home to store insulin rather than travelling miles to a doctor's surgery) they experienced in relation to the project. The project dataset provided by the ministry assisted in the formulation of the dynamic hypothesis and testing of the offered model. Furthermore, the formulation of the simulation model used some generic SD structures (*e.g.*, rework cycle) from various disciplines (*e.g.*, project management).

The relevant SD simulation model has been verified and validated in order to assess the sustainability (social, economic, environmental, and administrative) (Elkington, 1999) of this long-term project by formulating of a systemic dynamic hypothesis through a Causal Loop Diagram (CLD) (see Table 2 and Figure 3). This CLD model, using the Vensim tool (version 8.2.0), highlights the structures of the innovation, and sustainability and project model (see Figure 3). The integration of innovation, sustainability, with MoP is used to broaden the application of systems thinking to a project; it has been extended to encompass all the metaphases of the life cycle (see Figure 1).

Table 2: Causal loop diagram notation (Sterman, 2000).

Name	**Notation**	**Description**
Causal positive link	X → Y (+)	If X increases, then Y increases above what it would have been.
Causal negative link	X → Y (-)	If X increases, then Y decreases below what it would have been.
Positive (reinforcing) loop	(+) or (R)	Reinforcing loop identifier circulates clockwise direction as the loop to which it corresponds.
Negative (balancing) loop	(-) or (B)	Balancing loop identifier circulates counter-clockwise direction as the loop to which it corresponds.

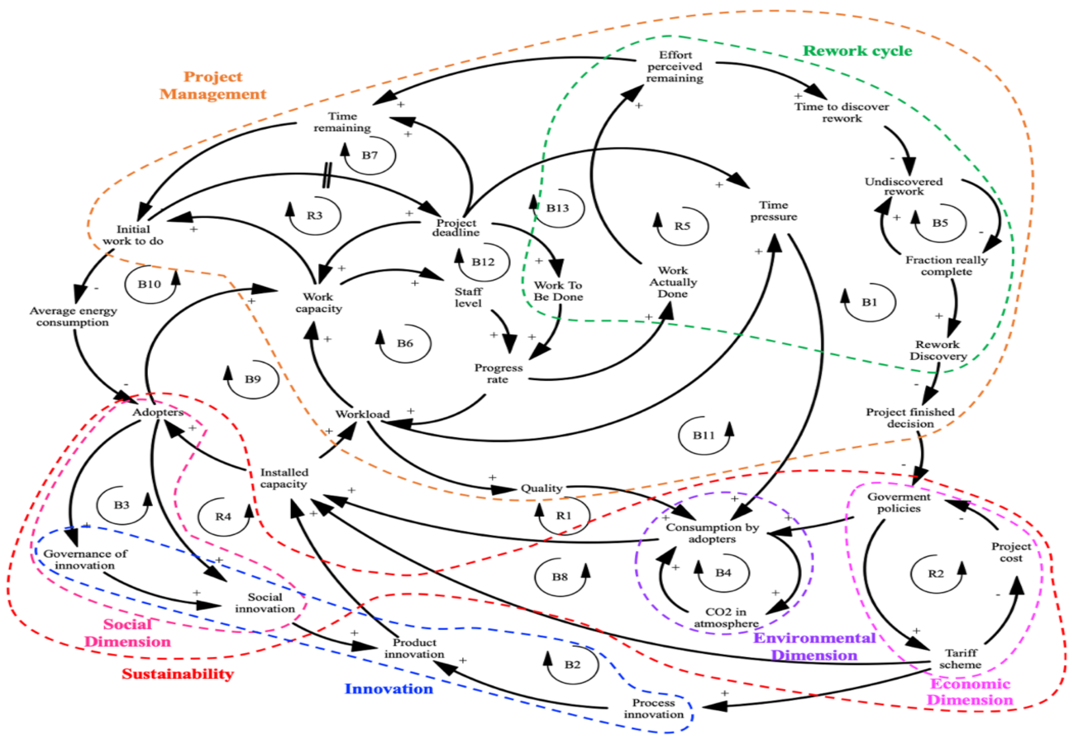

Figure 3: Causal Loop Diagram of the Systemic (Qualitative) Dynamic Hypothesis (Calderon-Tellez, 2022).

The Stock and Flow diagram (SFD), presented in Table 3 and Figure 4, represents the simulation model (step 3 in figure 2 (Sterman, 2000)) that was developed in Stella software (version 1.9.5). Data on the case study project (from the Colombian Ministry of Mines and Energy) is used with the model. The SFD (see Figure 4) establishes social, economic, and environmental sub-systems. These subsystems are discussed further with the project scenario introduced in section 4.2.2. The social sustainability dimension highlights the modelling structure for calculating cumulative householders that adopt solar panels as the population that evolves over time (see Figure 5). This informs efficiency capacity calculations. The environmental sustainability dimension highlights the modelling structure for calculating cumulative CO_2 emissions that evolve over time (see Figure 6). The economic sustainability dimension highlights the modelling structure for calculating costs with different tariffs (see Figure 7).

This SD model was validated (*e.g.* using Theil's inequality statistics (Sterman, 2000)) with the completed solar energy project in order to gain confidence in the simulation model's predictions. As scenarios were explored using the model, key feedback loops, shown in Figure 3, were discussed with the ministry, and throughout the process participants have reported the model offering useful explanatory insights. Innovation is also featured in the model with reference to product innovation and process innovation (see Figures 1, 3 and 4) within the execution of the project. Calderon-Tellez and Herrera (2023) use process innovation scenarios to trial the model and assess project impact.

Table 3: Stock and flow symbols (Xu and Zou, 2021, p. 19)

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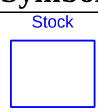
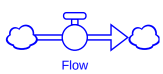
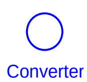
Name	**Symbol**	**Description**
Stock		The level of any variable in the system.
Flow		The rate of changes in stock, which can cause the increase or decrease of a stock.
Converte r		It connects stock and a flow in a complex setting, used for intermediate calculations.
Connect or		It denotes connection and control between system variables, showing the causality.

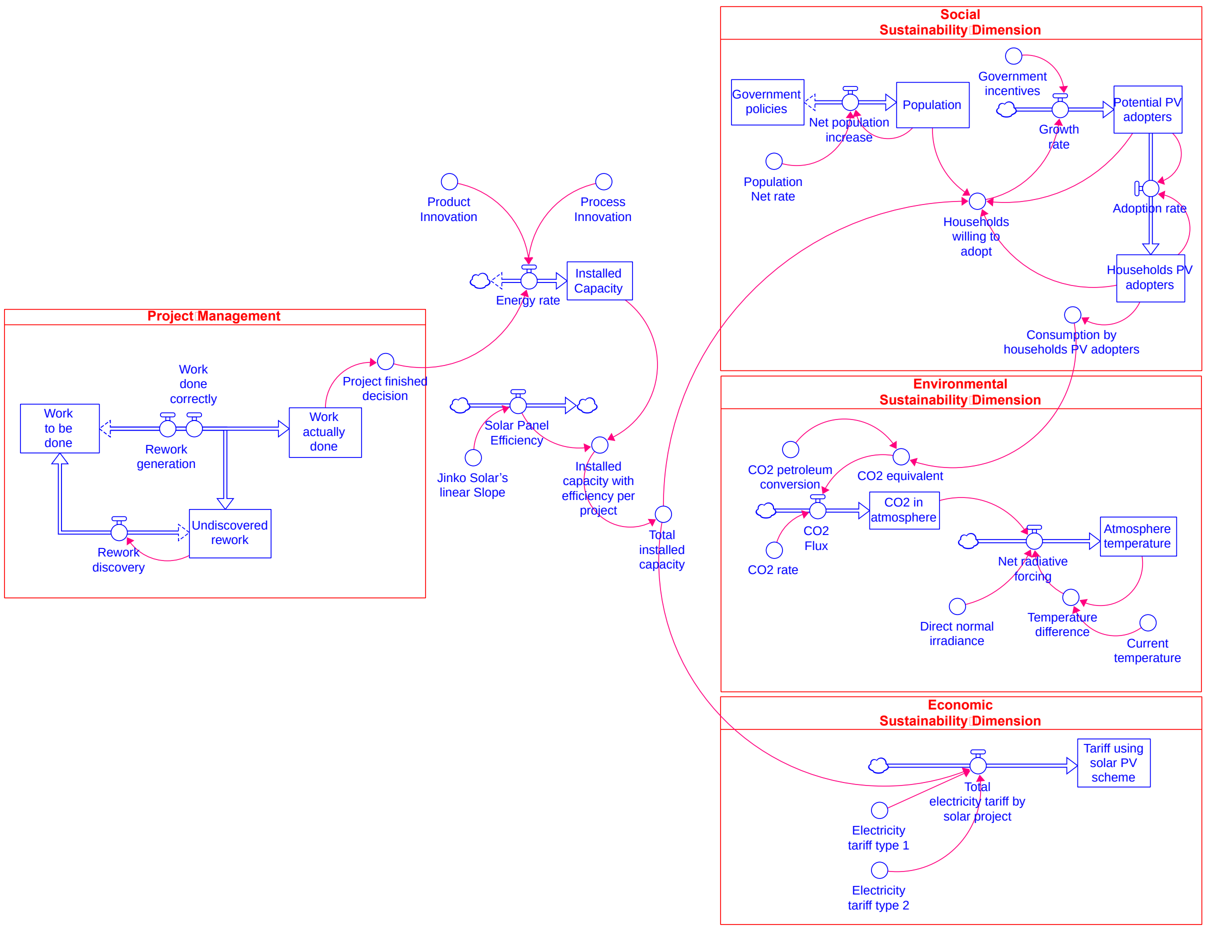


Figure 4: Expanding the rework cycle with installed capacity (produced by the project) to integrate project management with innovation and sustainability (Calderon-Tellez, 2022).

Applying the SD Model to a Project-Based Scenario

This exploration of project front-ending is associated with an adaptive approach (Morris, 2017) to countering anthropogenic climate change. It can assist strategic decisions that substantiate the shaping of the innovative project. The ISMP SD model can assist in exploring scenarios that can be used to inform long-range explanatory planning. Using the modelling to investigate sets of connected project decisions and impacts on project performance indicators can provide insights to dynamic behaviour within a project.

An illustrative scenario for the Orinoquia Solar PV project that was developed and modelled in this research, compares two energy technologies (*i.e.* solar and fossil fuel), and changing the type of innovation. The SD model simulates the two different energy scenarios in order to understand the dynamic behaviour of the system. That is to say, the simulation of the sustainability dimensions predicts the different impacts (see Figure 5) over time. The use of simulation, both in developing scenarios and in applying a model, in project management can be used to support project decision-making. This can have particularly significant impacts in application to support decisions made in a project's front-end phase and an important setting for using this approach can be for setting up learning across a programme of related projects, such as the energy programme example considered in this paper. Selecting the type of technology is part of the strategy in the long-range planning. A single relevant scenario is identified to compare solar with fossil fuels that has explanatory insights to this planning issue, and connectivity with the dynamic behaviour informing strategic decision making. Impacts on the three elements: economic, social, and environmental, of the TBL are considered in turn as discussed below.

Within the area considered by the case study, the need to satisfy household energy consumption needs (for 82 families) is a core component of social sustainability (Elkington, 1999) within project outcomes considered here. Both projects (solar and fossil fuel) are, therefore, designed to generate 61 kW. The solar PV project (considered to be 25 years of solar PV linear performance) started with 61 kW, but once the project was completed, it decreases 55.1 kW due to the solar panel efficiency of 97.5%. Meanwhile, the fossil fuel project remains at 61 kW until the 318th month (25 years) as shown in Figure 5[5].

[5] In this version, consumption modelled here does not include changes in population rate that might also become relevant over a long-term period.

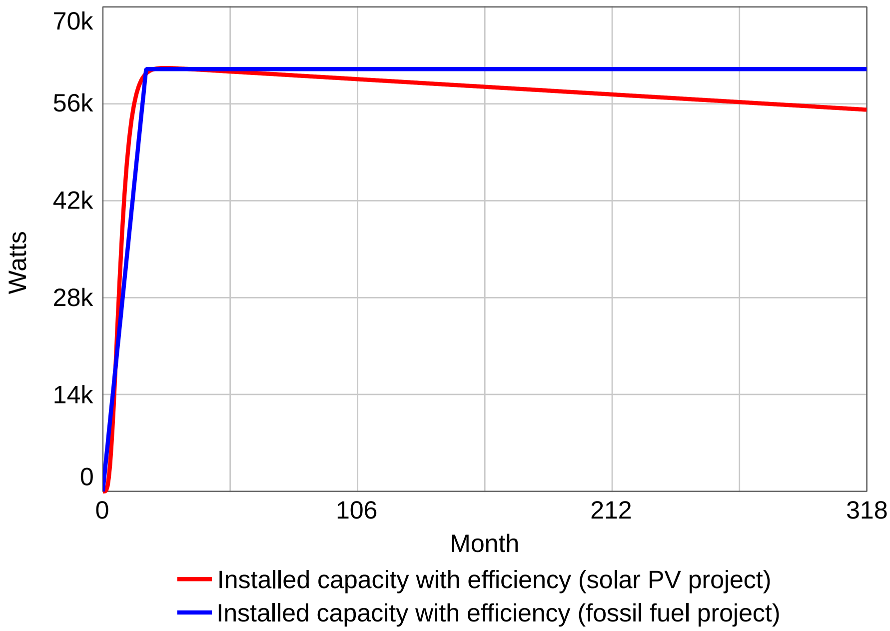


Figure 5: Social Dimension: installed capacity produced by the project in the long-term (25 years)

Considering the environmental sustainability (Elkington, 1999) outcomes of the project, the modelling considers the CO_2 emissions produced by the project in the long-term (25 years). The solar PV project is considered as renewable energy and that it does not generate CO_2 emissions[6]. Meanwhile, the fossil fuel project predicts that CO_2 in the atmosphere increases by 528% in the 25 years after project completion, as shown in Figure 6.

[6] Other applications of this approach could also extend this measure to consider embodied carbon.

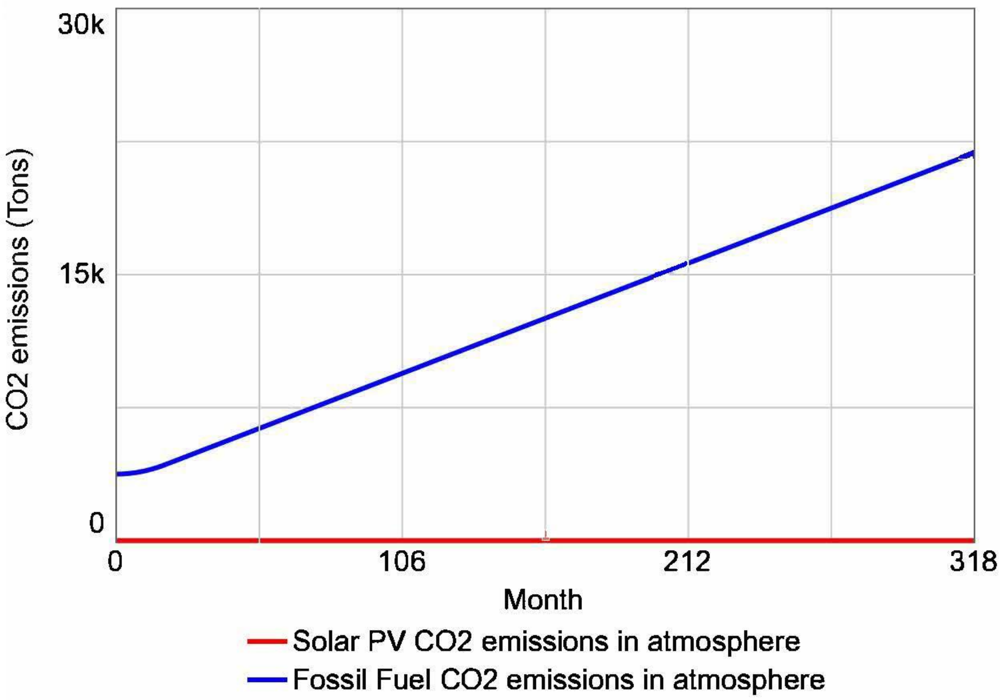


Figure 6: Environmental Dimension: CO_2 emissions generated by the project in the long-term (25 years)

Tariff scheme comparison, between solar PV panels and fossil fuel generators, is modelled to consider an economic sustainability factor (Elkington, 1999). Solar PV project costs are higher in comparison to those of fossil fuel projects when the analysis is taken over a short period of time. The solar short-term PV project cost of USD $541k, and the fossil fuels project short-term cost is USD $180k, i.e., a significantly lower cost for the fossil fuel in comparison to the solar PV one. In contrast, long-period analysis shows there is a higher tariff for the use of fossil fuels in comparison to a tariff for a solar PV scheme. The solar PV project has a tariff of USD $156k after 25 years of using a solar PV scheme. Meanwhile, the tariff of USD 827k for using fossil fuels (i.e. a high tariff in comparison to the solar PV energy panels). In other words, the economic sustainability aspect shows a higher tariff for fossil fuels 25 years after the project is completed as shown in Figure 7.

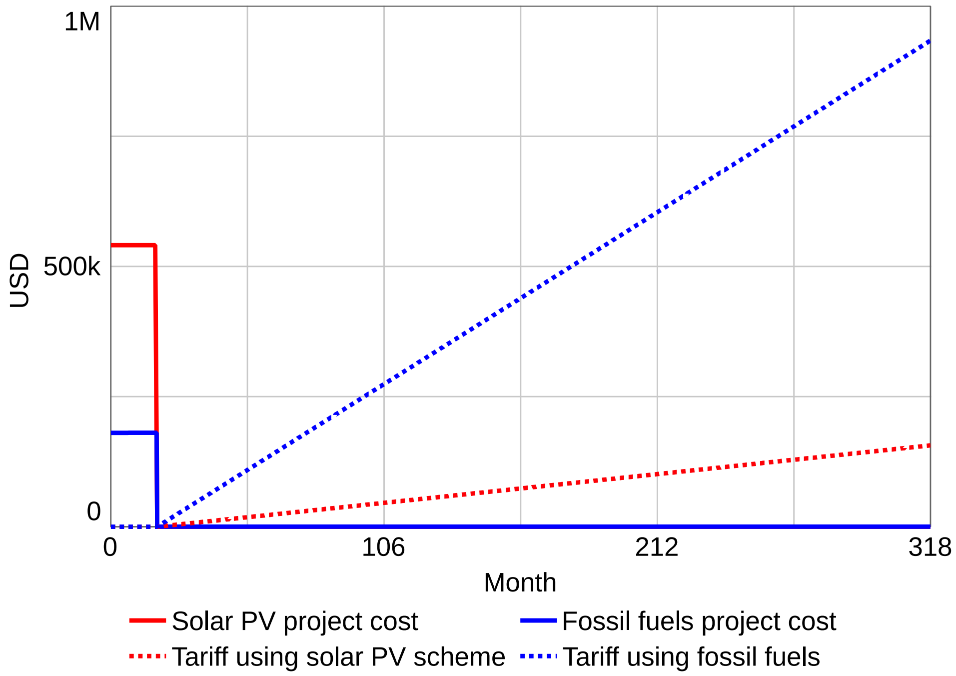


Figure 7: Economic Dimension: Cost generation in the long-term (25 years)

In building and applying an SD model linking project to outcomes, the exploratory case study developed here supports further development of project management practice into the context of projects for sustainability. The illustrative comparison scenario generated predictive insights with respect to agreed TBL goals (linked with project success), to inform strategic decision-making and long-range planning in projects for sustainable outcomes. Relevant SD models can inform the development of projects' sustainable viability and facilitate conversations which inform strategic project decisions.

DISCUSSION

The MoP (Morris, 2013; 1994) paradigm is viewed as an open system and is strongly connected with the Systems Movement. Anthropogenic climate change provides the context which promotes the importance of innovation and sustainability, leading to theoretical and practical gaps within the project management discipline. The ISMP theoretical framework builds upon the research directions for project management (Winter *et al.*, 2006), with a focus on innovation and sustainability theory (see Figure 1).

The ISMP framework is organised by systems thinking (*i.e.*, emergence and hierarchy, communication and control). It uses an extended project life cycle model, adding the ecosystems impact phase (see Figure 1). This highlights gaps, relating to strategic decisions, in MoP practice (e.g., how to consider sustainability viability of innovation decisions). Critically, informed strategic decisions with regards to sustainable innovative project solutions are important and represent connectivity between short (*i.e.* project management success) and long (*i.e.* project success) term management decisions. To support the consideration of sustainability viability in project decisions, a need for a systems-based simulation model, to connect to an identified real-world problem, is identified. After considered review, the SD technique has been selected, which is links with the latter pair of systems thinking ideas of communication and control.

The ISMP theoretical framework assists in organising the conceptual boundaries of the real-world system and sub-systems. Following the ISMP framework, aspects of innovation and sustainability theories are translated into variables within the SD model that is created using specialist software. The approach developed attempts to illuminate structural complexity of the extended life cycle processes with respect to a single selected case study that is set in the context of the Colombian renewable energy problem, and care is taken to align with the definition of sustainability (Morris, 2017). Working closely on the case study with key stakeholders revealed the importance of both short-term (project management success) and long-term (project success) objectives, which inform management decisions with respect to this real-world energy problem. This exploratory research supports Silvius and Schipper (2014) view that sustainability shifts the scope of project management (*i.e.,* from managing time, budget and quality, to managing social, environmental and economic impact), and the work also highlights interdependency between different objectives. These short and long-term objectives assisted in shaping the content of the relevant SD model. The integration of sustainability impacts into the understanding of project success (and an individual projects' objectives) will change the content of a project and, in this illustrative case study, shape the installed capacity produced by it. SD modelling approach can be used to support understanding of connections between decisions of project management and the ecosystems impact produced.

The content of the SD model is informed by ISMP theory and working with key stakeholders to reveal the structural complexity (or systemicness) of the project life cycle processes. Additionally, the iterative process (see Figure 2) to constructing this SD (Sterman, 2000) provides insightful modelling guidance. It was recognised that synthesis was guiding the construction of the model. The building of this subjective model used previous SD structures from innovation, sustainability and project management. These structures were integrated into relevant subsystems of the offered SD model. The overall subjective model hypothesis has been built around that unique real-world problem situation. However, there are *repeatable* (or common) structures (*e.g.* the rework cycle (see Figure 4)) underpinning the completed SD model. These repeatable structures can be found within identified sub-systems of the model (see Figure 1 and Figure 3). Furthermore, these common SD structures (and their dynamics) can be found at specific system levels for identified real-world MoP problems. These common structures can be viewed as systemic dynamic hypothesis for identified sub-systems. Furthermore, extending the application of this approach in future research, there is potential for identification of archetype structures (Senge, 2006) and this form of *repeatability* can be connected to integrative SD practice.

The SD model was validated through collected data from a completed Colombian solar energy project. The offered SD model reveals relevant systemic processes within the boundaries of the ISMP life cycle model (see Figure 1). These qualitative (*i.e.* causal loop diagram) and quantitative (*i.e.* stock and flow) models are viewed respectively as a systemic (qualitative) dynamic hypothesis (see Figure 3) and systemic (quantitative) dynamic hypothesis (see Figure 4) which illuminated the structural complexity of that life cycle process.

The developed SD simulation model can inform strategy and long-range planning decisions through exploring different scenarios. Moreover, the offered systemic model extends the application of systems thinking to support broadening of project management practice (*i.e.* from front-ending to ecosystems impact). This Colombian evaluation study is undertaken in the front-ending phase and is viewed as an adaptive approach (Morris, 2017) to reducing greenhouse gases to counter climate change. A scenario comparing two energy technologies (*i.e.* solar and fossil fuel) through the SD simulation model offers some dynamic behaviour insights, and aspects of TBL (*i.e.* social, environment, economic) are used as relevant performance indicators for long-term energy decisions (*i.e.* project success). Furthermore, the reduction of CO_2 emissions is an important benefit of this solar project and to addressing society needs.

The SD model can explore some '*what if*' strategies (*e.g.,* various tariff values) to achieve project success. Again, this exploratory research supports Silvius and Schipper (2014) perspective that sustainability facilitates a paradigm shift in project management (*i.e.* from predictability and controllability approach, to flexibility, complexity and opportunity approach), and also the need to explore the long-term dynamic ecological impact over time. This work also illustrates the possibilities of SD model connectivity with the project's strategic envelope (Morris, 2013), and a front-ending tool for facilitating energy project conversations that guide strategic management decision-making.

Morris and Geraldi (2011) stress the importance of understanding the consequences of front-ending management decisions and activities which impact upon the build and downstream implementation. This exploratory research offers the potential for SD as a strategic decision support tool (or as a form of flight simulator) to address project planning challenges. Additionally, this offered approach can assist the aim of sustainability development definition (Brundtland, 1987; Morris, 2017) with regards to exploring downstream dynamic ecological impacts over time. The ecosystems impact phase is a broad idea that can be moulded to different real-world energy problem situations. The ecosystems impact phase identifies relevant attributes (linked with TBL or perhaps in the future with Sustainable Development Goals (SDGs)) and related variables, and the dynamics consequences can be examined over time through an ISMP framework and connected SD model.

From this exploratory research, it is believed that subjective and relevant SD models can assist with *strategic* project management decisions. Furthermore, this systems approach can be connected with the MoP paradigm and alternative project management theory (Winter et al., 2006). Additionally, it could complement traditional project management associated methods which assist with *tactics* and *operational* project management decisions. This multi-methods approach is proposed to assist project management practitioners to achieve both project success and project management success with respect to complex projects for sustainability.

CONCLUSION

The MoP paradigm espoused by Peter Morris encourages broader theoretical and practical thinking to achieve both short-term (*i.e.,* project management success) and long-term (*i.e.,* project success) objectives. A MoP approach is critical to developing and delivering innovative and sustainable energy project solutions within the anthropogenic climate change context. Responding to this, this paper introduces a ISMP theoretical framework built on MoP that extends the project life cycle to support the assessment of sustainability viability of project decisions on innovations. This has highlighted some practical gaps for project practice (*e.g.* scenario exploration, strategic decision-making, and long range planning). A System Dynamics (SD) based technique has been used to reveal and communicate the structural complexity across this extended project life cycle and this approach has been applied to a Colombian renewable energy project. Useful results have been generated and opportunities identified to further develop this approach for wider application.

The utilization of the ISMP theoretical framework, together with working with key stakeholders, has assisted in the development of the SD model. This exploratory research suggests that subjective and relevant SD models can contribute to addressing identified practical project management gaps. The dynamic behaviour patterns of the model facilitate informative discussions and management decisions with respect to evaluating innovative solutions to the identified problem, which can guide future stakeholder actions. Importantly, engaged scholarship provided guidance in developing formal (systems) knowledge to the identified practical problem.

The SD model for a project is viewed as a strategic decision-aid that addresses identified gaps for broadened project management practice. It is also of note that SD (categorised within hard systems thinking) can be applied throughout the updated project life cycle model (see Figure 1). Previously soft systems approaches and hard systems approaches have tended to be separated into considerations of the strategic envelope and the technical core, respectively.

Future research could explore the connectivity of soft systems thinking and associated approaches (*e.g.,* Soft System Methodology) with SD within the context of the ISMP framework. This could lead to the development of a multi-paradigm multimethodology (Mingers and Gill, 1997) (see Figure 1). Moreover, there is a need to undertake more renewable energy case studies and construct more subjective and relevant SD models in order to gain confidence in the exploratory offerings. These quantitative SD models are viewed as systemic (quantitative) dynamics hypotheses which reveal the structural complexity of the ISMP framework (see Figure 1). This can be used to establish common (*repeatable)* structures and archetypes, within various subsystems, which are able to be confirmed or *refuted* by stakeholders, and to represent the MoP paradigm and connecting stages of the project life cycle for practice.

ACKNOWLEDGMENTS

This work was supported by the Colombian Ministry of Science, Technology, and Innovation – Minciencias Scholarship Program Nº 756, and by the Colombian Army Resolution Nº 330. The authors would like to acknowledge receipt of funding from the Universidad Militar Nueva Granada. The authors would like to thank two anonymous reviewers for their comments on the paper and Professor Andrew Edkins, as Editor, for his constructive feedback further developing the paper.

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